Fundamentals of Genetics (BIOL2107)

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Note: *always use your Carleton email account to contact me and put 'BIOL 2107' in the subject line

What is Genetics?

- **the science of heredity (textbook definition).**
- **according to the textbook: heredity is the way genes transmit physiological, physical and behavioural traits from parent to offspring**
- **the study of heredity (WHO)**
- **the branch of biology concerned with the study of heredity and variation in organisms (Collins English Dictionary).**
- **the study of heredity and the variation of inherited characteristics (Oxford Dictionary)**

Why study genetics?

- To understand where we come from
- To understand the living world around us
- To understand the origin of cultivated foods and livestock and to potentially modify these.
- To understand, treat and prevent disease

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Genetics as we know it is a relatively new science

a hereditary connection between parents and children was recognized, but the mechanisms were not appreciated

Greek philosophers and beyond

- Aristotle thought that males produced highly purified reproductive blood that mixed with female blood.
- Hippocrates speculated that "seeds" were produced by various body parts and transmitted to offspring at the time of conception… this concept of pangenesis persisted for centuries.
- Even Charles Darwin theorized that 'gemmules' or 'pangenes' were produced by every somatic cell and tissue in the body. These came together in gametes and were passed on to the zygote.

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18th Century Europe

Preformatism vs Neoformatism

During the 1700s, Dutch microscopist Anton van Leeuwenhoek discovered sperm. Challenged preformatism.

The concept of homunculus: preformed human in sperm (Nicolaus Hartsoeker).

Problems that this theory couldn't explain:

- Why do some of the mother's traits show up in the offspring?
- Why does only one baby (usually) develop from over 15 million sperm?

Nicolaus Hartsoeker

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18th Century Europe

A competing concept posited that the little human was in the ovum and that sperm stimulated its growth.

How did the father's traits transferred to offspring?.

Spermists vs Ovists

This theories seem ridiculous to us now

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The biological information in DNA generates an enormous diversity of living organisms

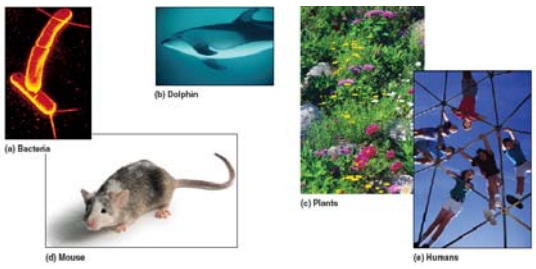

Fig. 1.1

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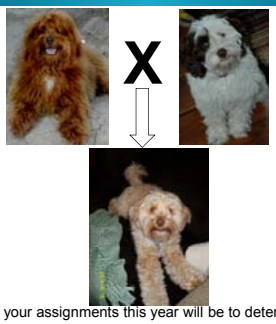
Why doesn't my dog's coat look much like the fur of either parent?



One of your assignments this year will be to determine the coat colour genotypes for this cross

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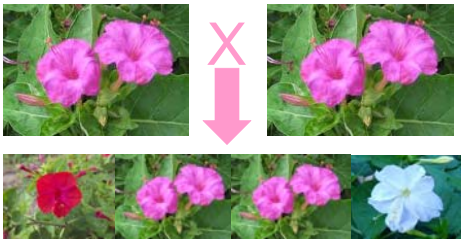
What do you get when you cross pink four o'clock flowers?



A mix of Red, Pink and White in a 1:2:1 ratio

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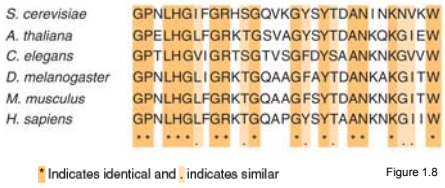
Many genes have similar functions in different organisms

Comparison of gene products in different organisms can reveal identical and similar amino acid sequences

e.g. cytochrome C protein from six species



* Indicates identical and . indicates similar

Figure 1.8

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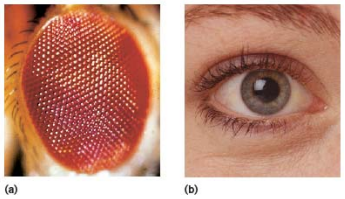
A gene from one organism can functionally replace a gene in another organism

Example: Pax6 gene is required for eye development in insects, mice, and humans

Expression of human Pax6 gene in Drosophila can induce eye development



(a) (b)

Figure 1.9

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Crops and livestock have been genetically modified for thousands of years

- wheat is a hexaploid, with three complete genomes termed A, B and D in the nucleus of each cell (2 copies of each).
- Breeding programs generate knew genetic combinations that have yielded favorable characteristics.
- How are seedless fruits and vegetables produced?
- The current widespread use of the term GMO (genetically modified organism) refers to an organism whose genome has been altered by the techniques of genetic engineering so that its DNA contains one or more genes not normally found in its genome (ie. transgenic organisms).
- An understanding of genetics will allow informed opinions on GMO.

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Genetics in the News

Organization of genetic information in cells

Genes are sequences of DNA that encode proteins or non-coding RNAs.

Chromosomes are structures that package and manage the storage, replication and expression of genes

A genome is the complete set of genes or genetic material present in a cell or organism.

The human genome:

- **24 kinds of chromosomes (22 pairs + X and Y)**
- **3 x 10^9 base pairs**
- **Encodes ~ 30,000 genes**

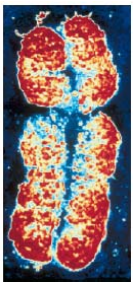

Figure 1.4

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Modern genetic techniques

Genetic dissection of model organisms
- **Inactivate a gene and observe the consequences**
- **Small inhibitory RNAs**
- **CRISPR**

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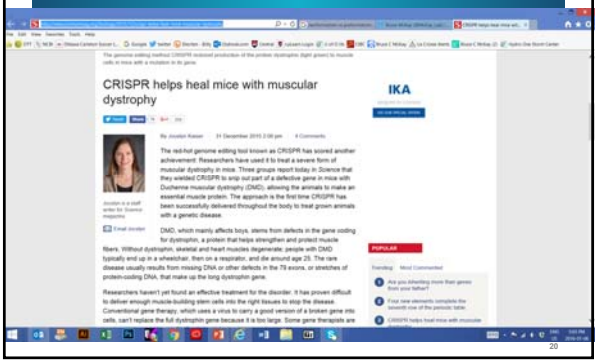
http://news.sciencemag.org/biology/2015/12/crispr-helps-heal-mice-muscular-dystrophy



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Modern genetic techniques

Genetic dissection of model organisms
- **Inactivate a gene and observe the consequences**
- **Small inhibitory RNAs**
- **CRISPR**

Genome sequencing
- **Human Genome Project**
- **Model organisms and other organisms**

Understanding higher-order processes that arise from interacting biological networks

Genomics can rapidly analyze thousands of genes
- **High-throughput DNA sequencing and genotyping**
- **Large-scale DNA arrays (chips)**
- **Synthetic lethal screens**

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The information in DNA is one-dimensional and is digital

Digital: a system based on discontinuous data or events

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Computerized analysis of chip hybridizations can be used to compare mRNA expression in two types of cells

Thousands of genes can be simultaneously analyzed

In this example, genes whose expression was altered by treatment with an experimental cancer drug were identified using a DNA chip

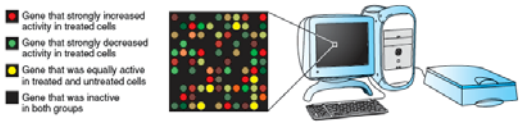

Figure 1.13c

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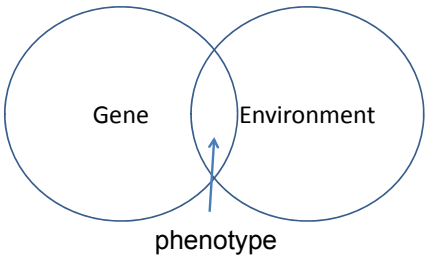
How does the environment factor into genetics?



Twins represent an interesting study population

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Genetic identity in monozygotic and dizygotic twins

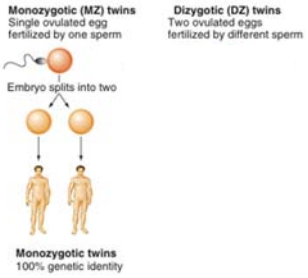
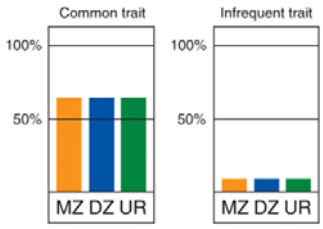


Figure 12.17.a

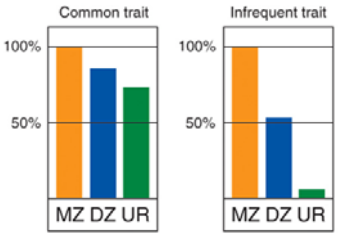
Percent concordance in monozygotic twins (MZ), dizygotic twins (DZ) and genetically unrelated (UR) siblings (adoption)



Low heredity... No measurable genetic influence

Figure 12.17.b.1

Concordance in monozygotic twins (MZ), dizygotic twins (DZ) and genetically unrelated siblings (UR)



Highly heritable... Strong genetic component

Figure 12.17.b.2

Health Home | Men's Health | Women's Health | Children's Health | Alternative Medicine | Diabetes | Heart Health | Allergies

HEALTH

Twins separated at birth reveal staggering influence of genetics

LIVE SCIENCE

WASHINGTON Jim Lewis and Jim Springer were identical twins raised apart from the age of 4 weeks. When the twins were finally reunited at the age of 39 in 1979, they discovered they both suffered from tension headaches, were prone to nail biting, smoked Salem cigarettes, drove the same type of car and even vacationed at the same beach in Florida.

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Contents lists available at ScienceDirect

Forensic Science International: Genetics

journal homepage: www.elsevier.com/locate/fsig

Finding the needle in the haystack: Differentiating "identical" twins in paternity testing and forensics by ultra-deep next generation sequencing☆

Jacqueline Weber-Lehmann, Elmar Schilling, Georg Gradl, Daniel C. Richter, Jens Wiehler, Burkhard Rolf*

ABSTRACT

Monozygotic (MZ) twins are considered being genetically identical, therefore they cannot be differentiated using standard forensic DNA testing. Here we describe how identification of extremely rare mutations by ultra-deep next generation sequencing can solve such cases. We sequenced DNA from sperm samples of two twins and from a blood sample of the child of one twin. Bioinformatics analysis revealed five single nucleotide polymorphisms (SNPs) present in the twin father and the child, but not in the twin uncle. The SNPs were confirmed by classical Sanger sequencing. Our results give experimental evidence for the hypothesis that rare mutations will occur early after the human blastocyst has split into two, the origin of twins, and that such mutations will be carried on into somatic tissue and the germline. The method provides a solution to solve paternity and forensic cases involving monozygotic twins as alleged fathers or originators of DNA traces.

Genetics can help you understand tabloid-like stories in the news

Technology is available to sequence individual genomes

What do you do or what could you do with this information?

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Important implications of genetics to social issues

- **This genetic information can be used to identify risk and guide lifestyle choices.**
- **But it can also be used to discriminate against people**

Figure 1.15

Canadian Coalition of Genetic Fairness (CCGF)

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Important implications of genetics to social issues (continued)

Proper interpretation of genetic information and understanding of statistical concepts is essential

Regulation and control of new technology

- **Transgenic technology (genetic engineering) is routine in many animals**
- **Should genetic engineering of human embryos be allowed?**

Guidelines must be established to prevent misuse of new knowledge in human genetics

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Course Learning Objectives

- Learn how traits are transmitted.
- Learn how genetic information is encoded.
- Learn the relationship between genes and traits.
- Learn the fundamentals of gene regulation.
- Learn about modern methods of genetic and genomic analysis and their implications for human health.
- Learn how *de novo* mutations contribute to disease.

BIOL2107A Fundamentals of Genetics
Winter Term 2015
Tentative Lecture Schedule

Lecture/Exam	Date	Subject	Readings*
Lecture 1	Thur Jan 7	Introduction	Chapter 1
Lecture 2	Tue Jan 12	Mendelian Inheritance I	Chapter 2
Lecture 3	Thur Jan 14	Mendelian Inheritance II	Chapter 2
Lecture 4	Tue Jan 19	Mendelian Inheritance III	Chapter 2
Lecture 5	Thur Jan 21	Chromosomal Basis of Inheritance I	Chapter 3
Lecture 6	Tue Jan 26	Chromosomal Basis of Inheritance II	Chapter 3
Lecture 7	Thur Jan 28	Linkage and Chromosome Mapping I	Chapter 4
Lecture 8	Tue Feb 2	Linkage and Chromosome Mapping II	Chapter 4
Lecture 9	Thur Feb 4	Linkage III and review	Chapter 4
Lecture 10	Tue Feb 9	Midterm I (Lectures 1 to 9)	Chapters 1-4
Lecture 11	Thur Feb 11	DNA, chromatin and chromosomes I	Chapter 5
break	Tue Feb 16	N/A	
break	Thur Feb 18	N/A	
Lecture 12	Tue Feb 23	DNA, chromatin and chromosomes II	Chapter 6
Lecture 13	Thur Feb 25	DNA, chromatin and chromosomes III	Chapter 6
Lecture 14	Tue Mar 1	Gene expression I	Chapter 7
Lecture 15	Thur Mar 3	Gene expression II	Chapter 7
Lecture 16	Tue Mar 8	Gene expression III	Chapter 7
Lecture 17	Thur Mar 10	Mutations and review period	Chapter 8
Lecture 18	Tue Mar 15	Midterm II (Lectures 11-17)	Chapters 5-8
Lecture 19	Thur Mar 17	Regulation of Gene Expression I	Chapter 10
Lecture 20	Tue Mar 22	Regulation of Gene Expression II	Chapter 11
Lecture 21	Thur Mar 24	Genome-wide Analysis	Chapter 15
Lecture 22	Tue Mar 29	Somatic Mutations and Genetics of Cancer	Chapter 16
Lecture 23	Thur Mar 31	Cancer and Genomic Instability	Chapter 16
Lecture 24	Tue Apr 5	Genome Sequencing and Human Health	Chapter 19
Lecture 25	Thur Apr 7	Review period	N/A
Final exam	TBD April 11-23	FINAL EXAM (Lectures 1-25)	

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BIOL 2107A, Fundamentals of Genetics, Winter Term 2016

Assignment dates

Assignment	Date	Topic	Chapters
1	Tue Jan 19	Mendelian inheritance	2
2	Thur Jan 28	Chromosomal basis of inheritance	3
3	Thur Feb 4	Linkage analysis	4
4	Tue Mar 1	DNA, chromatin and chromosomes	5 and 6
5	Thur Mar 10	Gene expression	7
6	Thur Mar 4	Regulation of gene expression	10 and 11

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Grading:

Assignments:	30 %
Midterm 1:	15 %
Midterm 2:	20 %
Final exam:	35 %

Assignments:

6 assignments
only your best 5 will count towards your grade.

Fundamentals of Genetics (BIOL2107)

CULearn: Announcements, information on the course, supplemental readings, practice questions, assignments, etc... will be made available on CULearn.

Fundamentals of Genetics (BIOL2107)

Missed exams:

- Notify me for mid-term exams or assignments.
- Notify the registrar for final exams.
- Student's petition must be accompanied by:
  1. a medical certificate clearly stating that the student was seen by a doctor on, or prior to, the date of the exam and was medically incapable of writing the exam at the appointed time,
  2. other official documents indicating that the student's absence was due to circumstances beyond their control.

Fundamentals of Genetics (BIOL2107)

There will be no make-up exams for students who miss a midterm. The weighting of the marks for the other midterm and the final will be adjusted equally.

The final exam will be scheduled during the regular examination period. It is the responsibility of the student to present during this period; in particular, holiday travel arrangements must not be made before the examination schedule is known.

Fundamentals of Genetics (BIOL2107)

Academic Accommodations: If you need special arrangements to meet your academic obligations during the term, you may make a request for accommodation, as follows:

Pregnancy or religious obligation: Write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details visit the Equity Services website: http://www2.carleton.ca/equity//ccms/wp-content/ccms-files/Student-Guide-card-09.pdf

Fundamentals of Genetics (BIOL2107)

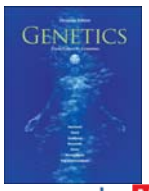
Students with disabilities requiring academic accommodations in this course must register with the Paul Menton Centre for Students with Disabilities (PMC) for a formal evaluation of their specific needs. For further information see: http://www2.carleton.ca/pmc/new-and-current-students/dates-and-deadlines/

You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at: http://www2.carleton.ca/equity/

BIOL 2107

Textbook & Resources Information

Winter 2015



connect

Mc Graw Hill Education

McGraw-Hill Ryerson

Next class: Tuesday

We will start the unit on Mendelian inheritance

"Brother Mendel! We grow tired of peas!"

Cartoon by J. Chase

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